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TASK OBJECTIVES

During the second half of 1999, we worked on VI and MODAGG algorithm testing, code testing and code deliveries, end-to-end test runs, error analysis, QA , pre-launch validation and SCF development. Specific objectives and tasks included:

- Algorithm development and VI deliveries,
- End-to-end testing of VI products with X-and N-day tests at MODAPS and the J-day test run. This served to revise and debug 250 m and 1km MOD13A1, MOD13A2 and MOD13A3 vegetation index products and add the latest QA ECS and MODLAND metadata requirements,
- Complete MODLAND aggregation code and MODAGG QA deliveries,
- QA and MODIS data analysis, including software, QA tools, network and hardware issues and the development of a data management plan,
- Error and uncertainty analysis of the vegetation indices,
- MODIS Quick Airborne Looks (MQUALs) testing and development,
- Validation activities including Konza Prairie, La Jornada, Mongolia, and LBA,
- Homepage and early images and results preparedness.

WORK ACCOMPLISHED

1. Algorithm Development:

There are a total of 6 vegetation index algorithms, of which four are currently baselined, including:

- MODPR13A1 (250m),
- MODPR13A2 (1km),
- MODPR13A3 (1km monthly), and
- MODPRAGG (250m production plan).

All of these algorithms went through a maintenance period to include a new set of metadata fields. Adjustments were made to the science code for better performance and upgrades were made to handle multiple production scenarios , maximum value compositing (MVC), constrained view angle - MVC (CVMVC), and BRDF -adjusted compositing with optimization schemes and user defined parameters.

We also started the preliminary design for the new, at-launch 500m global production plan, which calls for global 500m input data processing and eliminates, for the time being, the 250m data production and products. As a result, two new algorithms were developed, MODPRAGG and MODPR13A1. The 500m MODPRAGG was completed and delivered as version 2.2.2 after thorough testing and multiple discussions with the MODLAND production team. The MODPR13A1 is set for delivery during the 3rd week of January. We should note that even though we are now producing at 500m, the 250m production system will still take place on a separate system, and thus, both production scenarios are planned. The 500m VI production now includes both the enhanced vegetation index (EVI) and the NDVI, along with the blue, green, red, and NIR surface reflectances associated with the vegetation index computation. The original 250m VI production set-up did not include the EVI, due to the required 500m blue band. Also, the 250 m production system only allowed the NIR reflectances to be attached, since the red could be calculated from knowledge of NDVI and NIR.

2. End-to-end test runs:

We participated in three end-to-end tests, from Level1B to Level 3 algorithms. Our participation, as in the case of other SCFs, required us to accomplish the following:

- ordering data exercise (FTP push and pull),
- consulting the LDOPE QA database for quick evaluation of our algorithms,
- in-house QA/QC of our products,
- pre-launch adjustments dependent of test results and findings,
- design a semi-automatic data management plan for our SCF.

During the X/Y/N-Day tests and the more thorough MOSS2/MOSS3 and J-Day tests, we successfully completed the following:

- an evaluation of network throughput performance,
- an evaluation of algorithm performance,
- an evaluation of science code performance and,
- an evaluation of exception handling.

Our participation in these tests was very helpful in identifying and anticipating post-launch processing problems and helped us in preparing for real MODIS data.

During the same period we worked closely with the University of Montana and Boston University to identify problems with the aggregation algorithm, which is vital to the functioning of the algorithms from all three groups, since all the input to these algorithms comes from the MODAGG code. We're also in the process of redefining some of the science logic behind the aggregation code based on the experiences we encountered during the J-day and previous tests. We also worked closely with Andy Germain at NASA/GSFC on the network problems we were facing earlier as part of our post-launch readiness exercises. We currently report an acceptable to above average performance.

3. Post-launch readiness and activities:

At our SCF we performed many tasks to prepare our system for the large data processing expected post-launch. All the exercises indicate that we will be capable of achieving the goals set forth by the MODLAND team with respect to the “Golden Tiles”, full spatial and temporal processing, and the 5% global processing target. We made major modifications to our file systems in order to achieve those goals. We are also preparing ourselves for many science- and research-based modifications to the code once data starts flowing. These include checks and updates on the following:

- BRDF effects on the compositing code, since our algorithm only incorporates a Walthall BRDF model, in the post-launch period we need to test other available models and work on optimizing pixel selection,
- spatial and temporal continuity of the VI maps over certain areas of the globe (USA and Amazon area),
- resolution effects on global VI maps, which can be investigated from the multiple resolutions (in house).

4. Research and Prototyping Efforts:

We have continued to investigate the behavior of two-band vegetation index (VI) from a theoretical point of view to further understand the characteristics of VIs. The characteristic behaviors of VIs can be represented by using the vegetation isoline equations which has been derived from our previous efforts. Thus, understanding the dynamics of the vegetation isoline equations becomes very important. The analyses are summarized effectively by focusing on its slope, NIR-intercept, and the intersection between the vegetation isoline and a soil line. Two parameters used in the study are the leaf area index (LAI) and fraction of green cover (G.C.). One of the conclusions from this study is that the behavior of the vegetation isolines is different for variations of these two parameters. These variation patterns are explained analytically using the derived expressions.

We then investigated the inherent variations of two-band vegetation indices against variations of canopy background brightness based on the previous analysis. We choose eight VIs, including the NDVI, simple ratio, soil adjusted VI (SAVI), modified soil adjusted VI (MSAVI) and transformed soil adjusted VI (TSAVI). Again, an analytical approach was used to investigate the canopy background influence on these VIs. Starting from the vegetation isoline equations, we derived the expression of each VI in terms of the top-of-canopy red reflectance with canopy specific optical properties (transmittance and reflectance) and soil line parameters (slope and offset). The rate of VI variations against changes of the top-of-canopy red reflectance is also derived for all the VIs. We demonstrated the inherent variations of the VIs against the background brightness through numerical simulations and concluded that these variations can be explained analytically. The results are useful in assessing the quality of MODIS NDVI product and in the development of enhanced VI's.

5. QA/QC Activities for the MODIS VI Products:

We concentrated on two major tasks:
(1) the upgrade of the LDOPE QA tools to version 1.2 and their integration with the in-house, SCF QA tools, previously written by Wim van Leeuwen. Their functionalities still need further and more thorough testing, including with the MODIS synthetic data;
(2) the second area of concern deals with MODIS VI product quality examinations. In summary, the activities can be conceptually classified into three categories:

- QA activities to examine data consistency of the products,
- validation activities to examine and detect biases in the algorithms and products, and
- error/uncertainty analyses to theoretically evaluate/characterize and estimate the products' accuracies and uncertainties.

A science QA activity plan for the initial MODIS data set will be summarized and combined with Kamel Didan's production QA plan in January 2000. The results of these initial activities will be presented at the IGARSS' 2000 conference.

6. Error/Uncertainty Analysis of the MODIS VI Products:

Tomoaki Miura conducted an error analysis in atmospherically corrected surface reflectances due to the dark target-based atmospheric correction (DTAC). The resulting error and uncertainties in the VI products were also analyzed. Specific activities involved the collection and analysis of high-resolution reflectance spectra from the NASA reference report no. 1139 (NASA 1139 spectra), which were manually entered into a digital format. A C-code was then developed to convolve the NASA 1139 spectra to MODIS bandpasses (this code can be upgraded for other sensors). Another C-code was written for the DTAC and used to conduct the simulations. This code was based on the 6S radiative transfer code. The results of this work were presented at the AGU 1999 Fall Meeting.

7. Data Management Plan:

A detailed data management plan was prepared by Kamel Didan and Wim van Leeuwen. This is an ongoing work in progress and describes an integrated 'science computing facility' (SCF) management plan. The document helps us to identify system (hardware and software, I/O throughput, network, connectivity, security) requirements, improvements and issues that will need to be implemented and solved. The main focus is to provide more structure to data I/O, data processing, data extraction and documentation activities for the MODIS project. The document provides guidelines and tools to keep track of incoming and outgoing data, back-ups, archived data and documentation and prevent data redundancy, while maintaining efficiency.

The SCF (Figure 1/ Appendix 3) has been and is still being developed to do "real time" processing of MODIS data to produce vegetation index (VI) data for Quality Assurance (QA) and validation of the MOD13 VI. Basically, ingested data, data I/O and products will be processed and evaluated, after which they get deleted (after they served their purpose), temporary stay online (disk), get put on near-line media (Digital Linear Tape;

DLT7000 stacker), or get put on off-line media (8mm, DLT7000 tape). The 'networker' software (Legato) was purchased to manage and keep track of these data with a database (indexed), so these data files can be retrieved when necessary. Since the DLT stacker has a limited capacity, the data needs to be migrated from near line to off-line without losing track of the contents on the DLT.

Figure 2 (Appendix 3) shows an abstract representation of the VI algorithm, which incorporates upstream data, science algorithm, algorithm implementation, and downstream data. Each SCF is required to have a network connectivity to support approximately 5-10% of their relevant MODIS product from the MODAPS and GDAAC and 5-10% from EDC DAAC. The MOD13 products will be archived at EDC. LDOPE will handle the evaluation of approximately 10% of all MODLAND products, and each SCF is expected to examine 5% of their daily average data volume. Products made by MODAPS are sent to EDC DAAC for distribution and the MODLAND QA logs will be sent from the MODAPS to the LDOPE QA database. Each SCF will use the LDOPE QA database to:

- Infer the production status
- Infer quality of the product by their documented metadata
- Establish a list of products required to perform detailed QA
- Investigate the causes of detected failure
- Set science quality flags

The above scheme requires a two-way data exchange between the SCF and one of either LDOPE, GDAAC, EDC, DAACs (Figure 3/ Appendix 3). The algorithm product or the inputs required by the algorithm or both are downloaded as scheduled and in coordination with the golden tiles or alert notices from the LDOPE. Depending on whether the input or the actual product was downloaded the SCF will perform two tasks:

- Process the data (usually using a special algorithm version)
- Conduct QA analysis

8. MODIS PM- description of VI Product:

The vegetation index product for a Terra/ Aqua combined orbit period was prepared for the Data Products Handbook (see Appendix 2). Use of both MODIS sensors will provide an opportunity for 8-day products, given the increased number of acquisitions and availability of cloud-free pixels.

9. Meetings, Conferences, and Workshops:

Huete, A.R., “The Use of Low-Resolution Satellite Imagery in Arid Areas: Uses and Limitations”, ***Invited speaker,*** DOE workshop on "Developing New Technologies to Assess Vegetation Changes and to Reclaim Arid Lands for Mitigating Impacts of DoD and DOE Activities", Las Vegas, Nevada, Aug. 2 – 3, 1999.

Huete, A.R., "Konza Prairie Field Work", presented at the Land Validation Readiness Review Workshop, Goddard Space Flight Center, Nov. 17, 1999 (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/vrr_workshop.html).

Miura, T., "Mongolia: 1999 Results and U.S. – GLI 2000 Campaign", presented at the Land Validation Readiness Review Workshop, Goddard Space Flight Center, Nov. 17, 1999 (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/vrr_workshop.html).

Miura, T., and Huete, A.R., "An Error and Sensitivity Analysis of Atmospheric Resistant Vegetation Indices Derived from Dark Target-based Atmospheric Correction", poster presentation at the American Geophysical Union, Fall Meeting, Dec 13-17,1999, San Francisco, California, USA.

Gao, X., Huete, A.R., Ni, W., and Miura,T., "Optical - Biophysical Relationships of Pure Vegetation Spectra Without Background Contamination", poster presentation at the American Geophysical Union, Fall Meeting, Dec 13-17,1999, San Francisco, California, USA.

Yoshioka, H., Miura, T., Huete,A.R., "Inherent Variations of Two-Band Vegetation Indices against Variations of Canopy Background Brightness", poster presentation at the American Geophysical Union, Fall Meeting, Dec 13-17,1999, San Francisco, California, USA.

Ferreira, L., and Huete, A., "Assessing the Temporal and Spatial Patterns of the Brazilian Cerrado Through the Use of Spectral Vegetation Indices", poster presentation at the American Geophysical Union, Fall Meeting, Dec 13-17,1999, San Francisco, California, USA.

Proceedings

van Leeuwen, W.J.D., A. R. Huete, T. W. Laing, K. Didan, "Vegetation change monitoring with spectral indices: The importance of view and sun angle standardized data". EOS/SPIE Conference on Remote Sensing for Earth Science Applications. Florence, Italy. Sept 20-24, 1999.

Huete, A., K. Didan, W. J. D. van Leeuwen, H. Yoshioka, E. Vermote, "Global-scale analysis of vegetation indices for moderate resolution monitoring of terrestrial vegetation with SeaWiFS sensor". EOS/SPIE Conference on Remote Sensing for Earth Science Applications. Florence, Italy. Sept 20-24, 1999.

Miura, T., and Huete, A.R., 1999, "An Error and Sensitivity Analysis of Atmospheric Resistant Vegetation Indices Derived from Dark Target-based Atmospheric Correction", Abstract, *EOS, Transactions, American Geophysical Union* (Vol. 80, No. 46, p.).

Gao, X., Huete, A.R., Ni, W., and Miura,T., 1999, "Optical - Biophysical Relationships of Pure Vegetation Spectra Without Background Contamination", Abstract, *EOS, Transactions, American Geophysical Union* (Vol. 80, No. 46, p.).

Yoshioka, H., Miura, T., Huete,A.R., 1999, "Inherent Variations of Two-Band Vegetation Indices against Variations of Canopy Background Brightness", Abstract, *EOS, Transactions, American Geophysical Union* (Vol. 80, No. 46, p.).

Ferreira, L., and Huete, A., 1999, "Assessing the Temporal and Spatial Patterns of the Brazilian Cerrado Through the Use of Spectral Vegetation Indices", Abstract, *EOS, Transactions, American Geophysical Union* (Vol. 80, No. 46, p.74).

Upcoming Presentations

Yoshioka, H., T. Miura and A. Huete, "Development of Biophysical Parameter-Specific Spectral Vegetation Indices: Applications to Agriculture", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Miura, T., Yoshioka, H., and Huete, A.R., "On the Statistical Nature of NDVI and SAVI Variations Induced by Canopy Background Brightness", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Huete, A., K. Didan, T. Miura, H. Yoshioka, "Application of Enhanced Vegetation Indices for Tropical Forest Monitoring", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Dematte, J. A. M., A. R. Huete, Ferreira Jr., L.G., M. C. Alves, M.R. Nanni, Cerri, C.E., "Evaluation of Tropical Soils Through Ground and Orbital Sensors", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Huete, A.R., "Global Rangeland Assessment and Monitoring with Spectral Vegetation Indices", ***Invited Speaker***, Society for Range Management Symposium on Remote Sensing Research and Applications to Range Management, Annual Meeting of the Society for Range Management, Boise, Idaho, Feb. 14 –18, 2000.

Ferreira, L., A. Huete, H. Yoshioka, and E. Sano, "Preliminary Analysis of MODIS Vegetation Indices over the LBA Sites in the Cerrado Region, Brazil", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Gao, X., and A. R. Huete, “Validation of MODIS Land Surface Reflectance and Vegetation Indices with Multi-scale High Spatial Resolution Data”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Miura, T., A. R. Huete, K. Didan, W. J. D. van Leeuwen, and H. Yoshioka, “An Assessment of the MODIS Vegetation Index Compositing Algorithm Using the Quality Assurance Flags and Sun/View Angles”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Huete, A., K. Didan, Y. Shimabokuro, and L. Ferreira, “Regional Amazon Basin and Global Analyses of MODIS Vegetation Indices: Early Results and Comparisons with AVHRR”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Descloitres, J., N. E. Saleous, A. R. Huete, and E. F. Vermote, “MODIS land surface reflectance and vegetation index products compared to SeaWiFS and AVHRR”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Justice C., Hall D., Huete A., Muller J. P., Myneni R., Running S., Strahler, A., Townshend J., Vermote E., Wan X., Roy D., Decloitre J., “A preliminary evaluation of land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

10. Publications:

Leeuwen van, W.J.D., Huete, A.R., and Laing, T.W., 1999, “MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR data”, Remote Sens. Environ., 69:264-280.

Huete, A., Keita, F., Thomé, K., Privette, J., van Leeuwen, W.J.D., Justice, C., Morisette, J., 1999, "A Light Aircraft Radiometric Package for MODLAND Quick Airborne Looks (MQUALS)", *Earth Observer*, v.11, n.1, p.22.

Reynolds, C.A., Yitayew, M., Hutchinson, C.F., Huete, A., Slack, D.C., and Peterson, M.S., 2000, Estimating crop yields and production by integrating the FAO crop specific water balance model with real-time satellite data and ground based ancillary data, Int. J. Remote Sens. (in press).

Qi, J., Kerr, Y.H., Moran, M.S., Weltz, M., Huete, A.R., Sorooshian, S., and Bryant, R., 2000, Leaf area index estimates using remotely sensed data and BRDF models in a semi-arid region, (in press).

Yoshioka, H., Huete, A.R., and Miura, T., 1999, Derivation of vegetation isoline equations in red - NIR reflectance space, IEEE Trans. Geosci. Remote Sensing, (in press).

Miura, T., Huete, A.R., and Yoshioka, H., 1999, Evaluation of calibration uncertainties on vegetation indices for MODIS, IEEE Trans. Geosci. Remote Sensing (in press).

Yoshioka, H., Miura, T., Huete, A.R., and Ganapol, B.D., 2000, “Analysis of Vegetation Isolines in Red-NIR Reflectance Space” Remote Sens. Environ. (in press).

Gao, X, Huete, A., Ni, W., Miura, T., 2000, Optical - biophysical relationships of vegetation spectra without background contamination, Remote Sens. Environ. (submitted 12/99).

11. Validation/ MQUALS Calibration/ Testing and Development:

With the help of Remote Sensing Group in Optical Sciences at the University of Arizona, our Spectralon diffuse reference panel (Labsphere) which is used for MQUALs was calibrated in their laboratory to determine its bi-directional reflectance with reference to a NIST-traceable standard of reflectance. Based on the spectral response curve of MODIS and TM sensors (VNIR), band convolution was performed to derive the MODIS and TM-band equivalent lambertian property of the panel. Cross-calibration was also done for our other two $BaSO_4$ reference panels to derive their lambertian properties traceable to the MQUALs panel with the diffuse light corrected. We also established the cross-calibration coefficients among our four Exotech radiometers with 15 degree field of view. Two of them have MODIS filters and are mounted on the aircraft and the ground (for continuous measurements of site irradiance), respectively. Another two have TM filters and are generally used for ground transect measurements. Thus, once our radiometer with MODIS filters is calibrated using Optical Science’s laboratory, all our radiometers will have traceability to the MODIS sensor. We are planning to utilize the calibrated MQUALs packages to validate MODIS land surface reflectance and derived vegetation index (VI) products at a variety of test sites in the coming field campaigns, including 1) jointly with level 1b calibration sites over uniform areas devoid of vegetation; 2) at Walnut Gulch in the arid/semiarid watershed of southeastern Arizona and; (3) agricultural crop areas in Maricopa Agriculture Center (MAC) of Arizona. These validation activities will help to better understand the performance of the algorithm and accuracy of the products during the first 6 months after MODIS launch.

12. Validation/ The Konza Prairie Research Field Experiment Report, July 1999

Personnel from the University of Arizona, TBRS lab, included Fricky Keita (Airplane crew) and Karim Batchily, Hiroki Yoshioka, Laerte Ferreira , and Pamela Nagler (Ground crew). The objective of this field campaign was to utilize the MQUALS package for validation prototyping in a native tallgrass prairie. The MQUALS package was used to optically characterize top of the canopy reflectances , coincident with an ER-2 overpass and ground-based biophysical measurements. Four institutions participated in this experiment, bringing more than 17 researchers.

Site Description

The Konza field experiment took place at the Konza prairie research area, 8 miles south of Manhattan, KS July 12 through 14. The Konza prairie located in the Flint Hills on eastern Kansas is populated with the native tallgrass or bluestem prairie. This preserve area has a burning and grazing areas used to evaluate the effects of fire and grazing on plant composition. We concentrated our ground activities at the grassland site (1 D and 2 D), the numbers meaning years between burning. The two transects we drew bracketed the flux tower. The 1 km transect was located in the east while the 250m transect on the West Side. Vegetation was completely green on the 1 year burning site and more standing litter was encountered on the second year burning site. Clear differences between these two treatments could be seen.

Weather Conditions

Variable weather conditions were encountered. Skies were generally clear in the early morning until 10.30 am when skies became mostly cloudy. Perfect skies (sunny) were encountered during the ER2 overpass on Tuesday (DOY 194). On Sunday and Monday, the soil and grass were extremely wet in the morning due to the presence of dew. Tuesday, Wednesday and Thursday mornings were drier but extremely windy. On Friday we had the only rainfall of the campaign.

Experiment

A Cessna, model 172 owned by Kansas Air was used to perform the aerial survey with the following equipment:

- Dycam digital camera
- Exotech radiometer with MODIS filters (SN 3671).

A digital camera that will be used in the SAFARI 2000 validation program and the Labview data acquisition system, were used during the third day in order to test and compare the two packages. All the instruments were fixed on a mount that was specially modified for the field experiment. The modification included lowering the Exotech mount and making a special deflector. The deflector has a 45 degree and is made of aluminum. The use of the deflector plate will provide better protection of the equipment against high pressure winds. The mounting on the airplane was made by using special robust nylon straps tied on the belly of the airplane. The nylon straps are specially designed for use on airplanes. Before flying the instruments, a test flight was done to make sure that the modified mount can withstand the wind pressure. After inspecting the mount at landing, it showed no sign of damages and tear.

Dycam

The Dycam operation was considerably improved over previous attempys and acquisitions. The camera crashed fewer times and was definitely more stable than before. Even though the time lapse picture function is missing in the updated camera software, we found that taking the pictures manually using an on/off switch did not pose any problems. Using the manual function, the airplane operator has total control as to where to take pictures and how many, with the help of the ground crew. Another finding was that the Dycam digital camera is very sensitive to the power output and the camera is less likely to crash and is more stable when the power supply provides a stable current, therefore, we recommend the acquisition of a voltage regulator such as the one used by the GSFC crew.

Ground-based activities

Biophysical data was collected in Konza Prairie in conjunction with radiometric data (ground and aircraft) as part of the MQUALS testing and validation of the MODIS sensor:

- Reflectance measurements along a 1km transect, and the 250 m transect N-S and S-N and a 100 m transect E-W
- fAPAR measurements along the 1 km and 250 m transect,
- LAI measurements using LAI 2000 and biomass sampling
- a flux tower was assembled between two Konza sub-biomes, 1- and 2- year burn sites.

13. Validation/ Mandalgovi, Mongolia field campaign, August 1999

Hiroki Yoshioka and Tomoaki Miura participated in the 1999 Mongolia summer campaign and collected both radiometric and biophysical data of the area. The initial data analyses were completed through September and the results were presented at the MODLAND validation readiness meeting on November 17 at NASA/GSFC. A summary report of the field activities is being prepared. This site is one of the EOS Core validation site under the leadership of Dr. Yoshioka Honda of Chiba University.

14. Validation/ La Jornada wet season, Sept. 1999

In September, we went back to La Jornada (New Mexico) in order to collect ground and airplane data for the wet season, complimenting the dry season data collected in May 1999. The survey flights took place September 27th and September 28th at La Jornada and Sevilleta sites (short grassland). The MQUALS package was mounted onto the USDA-ARS plane out of Weslaco, Texas.

15. Validation/ SALSA study site, August-September 1999

During two ETM + overpasses, August 24 and September 10, we collected ground radiometer data at Kendall grassland site on the Walnut Gulch Experimental Watershed in southern Arizona. This was accomplished in coordination with Dr. Susan Moran of the USDA-ARS, who also collected a biophysical data set of the site.

16. Validation/ LBA-activities

Within the scope of the LBA project (Large-Scale Biosphere-Atmosphere Experiment in Amazonia), we finished a preliminary investigation concerning the seasonal patterns and spatial distribution of the major vegetation types encountered in the Brazilian Cerrado (savanna vegetation types). This investigation was based on a full hydrologic year (1995) of composited AVHRR local-area-coverage (LAC) data converted to normalized difference vegetation index (NDVI) and soil-adjusted vegetation index (SAVI) values. Three major spatial domains were readily observable, including the savanna formations/ pasture sites, the forested areas, and agricultural crops. These results were summarized in a manuscript to be soon submitted as well as presented at the AGU 1999 Fall Meeting.

We also initiated a comparative analysis of optical VI's (Landsat 5 – TM data converted to the MODIS vegetation indices - EVI and NDVI), and the synthetic aperture radar data (JERS-1 L-band) response to the major cerrado vegetation communities. This study, in which data from both the wet and dry seasons are being utilized, is being conducted in the Brasilia National Park, a 30,000 ha area of preserved cerrado near Brasilia. The Brasilia National Park will be the major validation site for the early MODIS VI images over the cerrado region. Thus, in December 1999, we also prepared a first draft of the field experimental design. The expectation is that MODIS vegetation indices at 250m and 500m resolution will be compared with biophysical vegetation measurements and simultaneously acquired aircraft and ground optical measurements in a field campaign to be conducted this coming April, 2000. A 'field experimental plan" for the Brasilia National Park is in preparation.

17. UPCOMING TASKS:

- Our big task is to find a replacement for our systems/ programmer position which is vacant at the moment, following the departure of Ms. Farideh Farahnak. Currently, nearly all coding and systems work is being handled by Dr. Kamel Didan, but he is in need of much help.

- We continue to build and adjust out TBRS group homepage to handle a general description of our work, our data management plan, and create a mechanism for the display of early images and results. The address of the homepage is: http://gaea.fcr.arizona.edu/MODIS/MODIS_Research.html

❖ Validation preparedness

1. Focus on the Tapajos LBA core site as well as Brasilia National Park cerrado site.
2. Work and coordinate with Dr. Honda of the GLI team a Japan-U.S. joint validation exercise in the Western U.S.A. Dr. Honda wishes to run some transects from western Montana to southern Arizona.
3. Coordinate with Dr. Honda of GLI the 2000 field campaign in Mandolgovi, Mongolia.
4. Coordinate with Modland and the Bigfoot people on this year's validation work at 1-2 Bigfoot sites, most likely Bondville and Harvard Forest.
5. Coordinate with Drs. Susan Moran and Stuart Biggar on this years campaign at Walnut Gulch Experimental Watershed, Maricopa Agriculture Center and calibration sites in Nevada. We wish to fly the MQUALS system at these sites and simultaneously acquire Landsat 7, MODIS, MISR, ASTER, and EO-1 data.

APPENDIX 1. (Abstracts)

A. Manuscripts

Yoshioka, H., Miura, T., Huete, A.R., and Ganapol, B.D., 2000, "Analysis of Vegetation Isolines in Red-NIR Reflectance Space" Remote Sens. Environ. (in press).

Abstract: Characteristic behaviors of the vegetation isoline were analyzed by focusing on its three properties: the slope, NIR-intercept and the intersection between the vegetation isoline and the soil line. These properties are the key factors in understanding variations of vegetation index values with changes of canopy background brightness, known as background noise. The analyses were conducted based on the vegetation isoline equation recently derived by using representation of canopy reflectance of the adding method. The isoline parameters, slopes and NIR-intercepts of vegetation isolines were numerically obtained by the SAIL canopy model. Some of the known behaviors of the vegetation isoline were simulated and analyzed in detail.

B. Presentations

Huete, A.R., "The Use of Low-Resolution Satellite Imagery in Arid Areas: Uses and Limitations", ***Invited talk***, DOE workshop on "Developing New Technologies to Assess Vegetation Changes and to Reclaim Arid Lands for Mitigating Impacts of DoD and DOE Activities", Las Vegas, Nevada, Aug. 2 – 3, 1999.

Abstract: Low resolution satellite imagery involves coarse spatial resolution data at relatively high temporal frequency. The utility of such data, as well as its inherent limitations, has been demonstrated in land surface monitoring, namely through the experienced gained with the Advanced Very High Resolution Radiometer (AVHRR). Such data sets provide for regional and repetitive coverage and allows for processing to cloud-free imagery. Seasonal profiles of the vegetation growing season are typically constructed via the use of the normalized difference vegetation index (NDVI) which is a measure of the amount and condition of photosynthetically-active vegetation at the surface. Inter-annual comparisons of vegetation have been made for change detection studies using the nearly 20-year AVHRR-NDVI data record. This has allowed for effective tracing of the expansion and contraction of the Saharan desert – and sub-Saharan Sahelian zones. AVHRR data is also utilized operationally in Famine Early Warning Systems (FEWS) and in monitoring the spread of vector-borne diseases. In this presentation we discuss the advantages and give examples of coarse resolution satellite imagery as well as its inherent limitations in arid and semiarid regions. The processing steps involved, such as compositing, atmosphere correction, cloud flags, and geometric considerations are also diagrammed and discussed. We present recently launched, or soon to be launched, satellite and sensor systems such as MODIS, SeaWiFS, VEGETATION, and GLI. New algorithms and equations and better ways to process long-term data sets, particularly in arid regions, are also presented. The new algorithms for long-term processing include albedo, surface temperature, enhanced vegetation indices, fire damage, and vegetation biophysical parameters such as leaf area index and net primary production. There is still considerable research and development needed to fully understand the potential of coarse resolution data in arid region, vegetation monitoring.

Huete, A.R., Didan, K., van Leeuwen, W.J.D., Yoshioka, H., and Vermote, E., "Global-scale analysis of vegetation indices for moderate resolution monitoring of terrestrial vegetation with SeaWiFS sensor", EOS/SPIE Symposium on Remote Sensing, 20-24 September, 1999, University of Florence, Italy.

Abstract: Vegetation indices (VI's) have emerged as an important tool in the monitoring, mapping, and resource management of the Earth's terrestrial vegetation. They are radiometric measures of the amount, structure, and condition of vegetation which serve as useful_ indicators of seasonal and inter-annual variations in vegetation and resultant_ climatic and anthropogenic influences on the environment.__ In this study, the Sea-viewing Wide Field-of-View sensor (SeaWiFS) is used to prototype and analyze coarse resolution monitoring of the Earth's surface with vegetation indices. A 16-day series of SeaWiFS GAC (4-km resolution) data for the period, September 15 to October 1, 1997, was collected over the entire globe and composited to cloud-free, single channel reflectance images. The images were degraded to 8km and corrected for Rayleigh scattering, ozone absorption, and water absorption.
Histograms and transects were extracted over four 'continental' regions, North America, South America, Africa, and Asia, representing a wide range of land cover types. The histograms of the individual bands and two vegetation indices were analyzed along with some transect plots crossing major transitional areas within each continent. Unique distributions of NDVI and EVI values were displayed in the histograms. The EVI had a more normal distribution of values over the global set of biomes while the NDVI was skewed toward higher values approaching saturation over forested regions. The NDVI mimicked the skewed distributions found in the red band while the EVI resembled the normal distributions found in the NIR band. The EVI was also found to greatly minimize smoke contamination over extensive portions of the tropics. Smoke was found to degrade histogram peaks in the NDVI and red channel but had minimal effects in the NIR and EVI histograms. As a result, major biome types within continental regions were discriminable in both the imagery and histograms. The results how that multiple indices are useful for effective monitoring of the diverse set of global biomes with the EVI being particularly useful in high biomass, forested regions.

van Leeuwen, W.J.D., Huete, A.R., Laing, T.W., Didan, K., "Vegetation change monitoring with spectral indices: The importance of view and sun angle standardized data". EOS/SPIE Conference on Remote Sensing for Earth Science Applications. Florence, Italy. Sept 20-24, 1999.

Abstract: Remotely sensed reflectance data is often acquired at variable view and solar geometric configurations. Although vegetation change detection and monitoring with NDVI (Normalized Difference Vegetation Index) or other spectral indices are very sensitive to the effects of solar and view angle geometry, tools and methods to correct for these effects have not yet been fully developed to monitor vegetation dynamics more accurately. Since the NDVI tends to increase with both larger view and larger solar zenith angles, the resulting variability in both view and solar zenith angles are important for inter-comparison of vegetation covers at different latitudes and seasons. The main objectives of this research were to: 1) demonstrate the importance of view and sun angle standardization of reflectance and spectral vegetation index data for vegetation change monitoring, 2) determine the use and limitations of BRDF models to standardize reflectance and spectral vegetation index data, and 3) present a vegetation density dependent sun angle correction of the NDVI.
BRDF (Bidirectional Reflectance Distribution Function) model parameters can be used to normalize and interpolate the surface reflectance to nadir view angles, using multi-angle cloud-free reflectance data (van Leeuwen et al., 1999. MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR data, Remote Sens. Environ., in press). The sun angle variability can be standardized by using a BRDF model, although the data necessary to standardize to a certain sun angle for a composite time interval is very limited, and thus would be less accurate outside of the observed sun angle range. If multi-angle data are not available, a second method allows us to extrapolate (nadir) satellite observations (e.g. Landsat) to a standard sun angle throughout the year by using predetermined linear regression relationships between sun angle and nadir NDVI values for a range of vegetation types. An empirical relationship between NDVI and solar zenith angle was determined based on nadir ground reflectance data collected with the Parabola and Exotech radiometers for a wide range of land cover types. Both methods were applied to one month of daily, atmospherically corrected, multi-angle SeaWiFS (Sea viewing Wide Field-of-view Spectroradiometer) land reflectance data, with promising results. The difference in NDVI due to a sun angle change form 20° to 70° can be up to 50 %, and is generally higher for forested regions then for

grassland regions. The NDVI values for very dense vegetated and bare soil surface areas are less affected by solar zenith angle effects. The magnitude of the effect of sun-angle is also demonstrated on a continental scale by using view angle standardized reflectance data and a vegetation density dependent relationship between sun-angle and NDVI. This research showed that the sun and view angle effects on the widely used spectral indices need to be standardized to improve the accuracy of vegetation change detection and vegetation and crop monitoring during the growing season and for the comparison of vegetation growth at a range of latitudes. It is intended to demonstrate the sun and view angle phenomena with actual MODIS (Moderate Resolution Imaging Spectroradiometer) data as soon as the MODIS land-products are becoming available after the July (1999) launch.

Miura, T., and Huete, A.R., "An Error and Sensitivity Analysis of Atmospheric Resistant Vegetation Indices Derived from Dark Target-based Atmospheric Correction", Presented at AGU 1999 Fall Meeting, December 13 – 19, 1999 in San Francisco, CA

Abstract: As a precise radiometric measure, spectral vegetation indices (VIs) have been utilized to monitor the Earth's vegetative cover from local to global scales. The atmosphere has been well known to introduce large variations in VI values unrelated to surface changes. The atmospheric resistant VIs, including the atmospheric resistant vegetation index (ARVI) and enhanced vegetation index (EVI), have been developed to reduce such atmospheric effects. The atmospheric resistance concept is based on the wavelength-dependency of path radiances. Atmospheric effects can also be corrected prior to the computation of VIs. One such atmospheric correction method utilizes dark targets (e.g., dark dense vegetation, DDV) observed within an image being corrected. The method assumes a surface reflectance value for the dark target in the visible bands and estimates atmospheric optical thickness from the path radiances over the dark targets and climatology of the area. Although the estimated atmospheric optical thickness is sensitive to the assumed surface reflectance value and the chosen aerosol model, the derived, corrected surface reflectances are not very sensitive due to "self-compensating" effects. However, it is also reported that these self-compensating effects are not very effective for bright targets (e.g., the near-infrared (NIR) part of the spectrum), resulting in larger errors. It is expected that errors in the derived surface reflectances may be correlated between bands due to the wavelength dependency of the atmospheric effects. Thus, we evaluated errors in the derived surface reflectances using the dark target-based atmospheric correction method and investigated the performances and resultant accuracies of the atmospheric resistant VIs. We also compared their performances with the normalized difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI).

Yoshioka, H., Miura, T., and Huete, A.R., "Inherent Variations of Two-Band Vegetation Indices against Variations of Canopy Background Brightness" , Transactions, American Geophysical Union, 1999 fall meeting, vol. 80, no. 46, p.F96.

Abstract: Vegetation indices (VI) show variations against changes of canopy background brightness for a constant vegetation canopy. The variation is inherent and unique to each index, because it is determined when the index formulation is fixed. In this study those inherent variations of two-band vegetation indices against the background brightness changes are derived and analyzed using the vegetation isoline equation for eight vegetation indices, namely the normalized difference VI (NDVI), simple ratio VI (RVI), perpendicular VI (PVI), difference VI (DVI), weighted difference VI (WDVI), soil adjusted VI (SAVI), modified soil adjusted VI (MSAVI) and transformed soil adjusted VI (TSAVI). The analytical expressions of the inherent variations include three forms, 1) representations of the indices as functions of only the red reflectance for fixed vegetation optical properties, 2) partial derivatives of the indices with respect to the red reflectance as measures of the rate of change against the variations of the background brightness, and 3) logarithmic derivatives of the indices for comparison of their variations among the eight indices. Numerical demonstrations of the inherent variations are provided and analyzed with a limited number of model cases. Some of the known behaviors of those variations are observed and explained with the derived expressions. DVI, WDVI and PVI are linear functions of the red reflectance for a constant canopy, indicating that the index values increase monotonically as the background becomes brighter. RVI, NDVI, SAVI, TSAVI and MSAVI decrease their values with the background brightness in the range of low to middle value of leaf area index (LAI), then increase in the range of large LAI value. This trend is caused by the fact that the NIR-intercept of the vegetation isoline, which is initially positive, turns to be negative as the LAI value increases, resulting positive value of the partial derivatives of the indices with respect to the red reflectance. It is concluded that this approach is a systematic way to evaluate the inherent variations of vegetation indices for the background brightness changes.

Yoshioka, T., Miura, T., and Huete, A.R., “Development of Biophysical Parameter-Specific Spectral Vegetation Indices: Applications to Agriculture” , ERIM 2nd International Conference on Geospatial Information in Agriculture and Forestry, January 10 – 12, 2000 in Orlando, FL

Abstract: Spectral vegetation indices (VI) are one remote sensing-based method utilized to estimate plant biophysical and structural parameters, such as leaf area index and fraction of absorbed photosynthetically active radiation. For effective local and regional applications of VI products, precise knowledge of the theoretical and empirical relationships between the VI and the target canopy parameters are indispensable. Although there are many studies which show empirical relationships between VIs and plant biophysical parameters, a more active approach is to design an index that can be customized to specific applications and/ or areas. In this paper, the theoretical basis of a customizable vegetation index is introduced. The index is a weighted average of the soil-adjusted vegetation index (WASAVI) with different adjustment factors. The design concept of WASAVI is to match the vegetation index isolines to the true vegetation isolines by optimizing these adjustment factors, allowing customization to each target field in , e.g., applications to precision farming.

Miura, T., Yoshioka, H., and Huete, A.R., “On the Statistical Nature of NDVI and SAVI Variations Induced by Canopy Background Brightness”, ERIM 2nd International Conference on Geospatial Information in Agriculture and Forestry, January 10 – 12, 2000 in Orlando, FL

Abstract: One of the most common approaches in remote sensing for measuring or monitoring crop growth is the empirical correlation of spectral vegetation indices (VIs) with such crop biophysical parameters as leaf area index (LAI), percent green cover, and fraction of absorbed photosynthetically active radiation (fAPAR). These empirical relationships are developed by a least-squares fitting criterion aimed to statistically minimize variations observed in data sets, in which VIs respond to factors not associated with green vegetation and the biophysical measurements are contaminated with measurement errors. As most of these techniques are based on normality assumptions, it is of interest to understand the statistical nature of these variations. In this study, we investigated the statistical nature of variations of two commonly used VIs, the normalized difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI), as induced by canopy background brightness. A set of equations were developed to transform density functions (variations) of canopy background reflectances to that of the NDVI and SAVI. The uniform and normal densities were examined as hypothetical distributions of the canopy background reflectances. The resultant NDVI densities were totally skewed to the larger values for both the uniform and normal densities, exhibiting strong non-normality for the latter density case. The degree of skewness was largest over a bare soil and decreased with increasing LAI values. The SAVI densities also resulted in an asymmetrical distribution although its variations were much smaller than the NDVI. These results show the importance of statistical nature of VIs in order to develop a more accurate and precise estimator of biophysical parameters.

Huete, A.R., “Global Rangeland Assessment and Monitoring with Spectral Vegetation Indices”, ***Invited Speaker***, Society for Range Management Symposium on Remote Sensing Research and Applications to Range Management, Annual Meeting of the Society for Range Management, Boise, Idaho, Feb. 14 –18, 2000.

Abstract: A consistent set of satellite, aircraft, and ground-measured reflectances were collected over grass-shrub conditions in Arizona, New Mexico, Kansas, and Mongolia. This effort was part of a validation campaign to assess the usefulness and performance of spectral vegetation indices from low-resolution satellite sensors such as the AVHRR, VEGETATION, SeaWiFS, and soon to be launch MODIS and GLI. Calibrated Exotech radiometers were used to conduct yoke-based transects and low altitude aircraft transects at all the locations. The experiments were conducted at numerous sun angles in order to adjust all data sets to a common sun angle irradiance condition. The standardized reflectances were then utilized to compute a few spectral vegetation indices, including the normalized difference vegetation index (NDVI), the soil-adjusted vegetation index (SAVI), and the enhanced vegetation index (EVI). The grasslands consisted of shortgrass and tallgrass prairies with annual and perennial species, and various levels of shrub cover. Vegetation parameters measured included biomass, leaf area index, percent cover, and canopy height. Satellite data analyzed included SeaWiFS and Landsat Thematic Mapper. The results showed that we were able to couple the ground- and aircraft-based VI's with those from the satellite. Furthermore, we found that all of the grassland sites fell onto a common VI - biophysical parameter regression line with most deviations attributed to the proportion of senesced or dead plant material as well as shrub contents. With proper standardization of satellite data with atmosphere correction and sun angle adjustment, remote sensing offers great potential in monitoring rangeland biophysical parameters.

Ferreira, L., A. Huete, H. Yoshioka, and E. Sano, “Preliminary Analysis of MODIS Vegetation Indices over the LBA Sites in the Cerrado Region, Brazil”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: The Brazilian Cerrado, the second largest biome in South America, comprises an intricate mosaic of land cover types, vertically structured as grassland, shrubland, and woodland. Due to intensive agricultural and grazing occupation, the Cerrado is today the most severely threatened biome in Brazil. Previous investigations, mainly based on temporal AVHRR data sets converted to the normalized difference vegetation index (NDVI), indicate that the dominant land cover types may be grouped into three spatial domains, encompassing the savanna formations and pasture sites, the forested areas, and the agricultural crops. In this study, we analyze the performance of the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices (NDVI and the enhanced vegetation index – EVI) over the major cerrado vegetation communities. In particular, early MODIS VI images over the cerrado region will be validated over the Brasilia National Park, a 30,000 ha area of preserved cerrado near Brasilia. MODIS vegetation indices at 250m and 500m resolution will be compared with biophysical vegetation measurements and simultaneously acquired aircraft and ground optical measurements in a field campaign to be conducted this coming April, 2000.

Gao, X., and A. R. Huete, “Validation of MODIS Land Surface Reflectance and Vegetation Indices with Multi-scale High Spatial Resolution Data”, IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Surface reflectance is a key component for many level 3 and level 4 MODIS products, such as land cover, snow cover, vegetation indices, leaf area index, and fraction of absorbed photo-synthetically active radiation. In this study, we attempt to validate the MODIS land surface reflectance and derived vegetation index (VI) products. Our validation will be implemented by scaling fine-grained surface measurements to several levels of MODIS pixel size (250m, 500m, and 1000m), then assessing the differences between these surfaces and the MODIS products. The fine-grained surfaces will be obtained by two independent methods: 1) a light-aircraft package flying at low altitudes to provide "ground truth" radiometric data free of atmosphere influences and; 2) high resolution satellite images (ETM+). The confidence and accuracy of using ETM+ imagery, combined with fine-grained surface/aerial measurements, to validate MODIS products will be assessed at a number of validation sites, including; 1) jointly with level 1b calibration sites over uniform areas devoid of vegetation; 2) at Walnut Gulch in the arid/semiarid watershed of southeastern Arizona and; (3) agricultural crop areas in Maricopa Agriculture Center (MAC) of Arizona. These validation activities over a variety of test sites will help to better understand the performance of the algorithm and accuracy of the products during the first 6 months after launch.

Miura, T., A. R. Huete, K. Didan, W. J. D. van Leeuwen, and H. Yoshioka, "An Assessment of the MODIS Vegetation Index Compositing Algorithm Using the Quality Assurance Flags and Sun/View Angles", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Spectral vegetation index (VI) products, as derived from satellite sensors with low spatial and high temporal resolutions, have been utilized for operational monitoring of terrestrial vegetation. These satellite products are both spatially and temporally composited in order to remove clouds, minimize atmospheric contaminations, and standardize sun/view angles. The compositing algorithm of the Moderate Resolution Imaging Spectroradiometer (MODIS) VI products emphasizes a global, operational view angle standardization. It utilizes a bi-directional reflectance distribution function (BRDF) model to produce nadir looking equivalent reflectance values if enough cloud free observations are available during a 16-day compositing period. Otherwise, a backup, maximum value composite (MVC) criterion that includes a view angle constraint is utilized to composite. In this study, we assess and characterize this new compositing algorithm using MODIS data and compare it with the conventional MVC algorithm. Our assessment specifically focuses on: 1) view angle distributions of the composited images, 2) relative frequencies of two compositing scenarios documented in quality assurance (QA) flags and their spatial distribution patterns, and 3) relationships of these properties with VI values.

Huete, A., K. Didan, Y. Shimabokuro, and L. Ferreira, "Regional Amazon Basin and Global Analyses of MODIS Vegetation Indices: Early Results and Comparisons with AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Vegetation indices have emerged as important tools in the monitoring, mapping, and resource management of the Earth's terrestrial vegetation. They are radiometric measures of the amount, structure, and condition of vegetation which serve as useful indicators of seasonal and inter-annual variations in vegetation. In this study, early images from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to evaluate the normalized difference and enhanced vegetation indices (NDVI, EVI) for global and regional vegetation monitoring. The histograms of the individual bands and the two vegetation indices are analyzed from hyperarid to moist tropical vegetation biomes and compared with the AVHRR-NDVI product. At the regional level, tropical forest monitoring and discrimination of land use conversions over the Amazon Basin are analyzed and compared with LBA field results at the Tapajos validation core site. The aerosol resistance properties of the EVI and extendedOsensitivity over dense vegetation are evaluated. The NDVI histograms are compared with the EVI as well as the AVHRR-NDVI.

Descloitres, J., N. E. Saleous, A. R. Huete, and E. F. Vermote, "MODIS land surface reflectance and vegetation index products compared to SeaWiFS and AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Improved spatial resolution and radiometric performance provide new capabilities to recent instruments such as MODIS. In particular, more accurate algorithms have been implemented to derive operational products from MODIS data for land applications. However, long-term time series analyses are essential to understand the inter-annual variability of land properties and in particular to monitor the vegetation. Therefore the recent MODIS land products have to be linked to existing comparable long-term data sets derived from older sensors such as AVHRR and SeaWiFS. This paper presents some early MODIS land surface reflectance and vegetation index products and compares them to similar products derived from SeaWiFS and AVHRR. The results of this comparison are discussed with respect to the characteristics of each of these instruments. The strengths of MODIS land products and their importance for land applications are highlighted.

Justice C., Hall D., Huete A., Muller J. P., Myneni R., Running S., Strahler, A., Townshend J., Vermote E., Wan X., Roy D., Decloitre J., "A preliminary evaluation of land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: The MODIS instrument is designed for improved observation of the land surface and investigators have been selected to provide the next generation of land surface data products. New capabilities in spatial and radiometric resolution have allowed for improved algorithms. A suite of MODIS land products have been designed to contribute to the study of terrestrial ecosystems, radiation budget and land use and land cover change. Products include surface reflectance and temperature, vegetation indices, fire, snow and ice cover, leaf area index, albedo, land cover and land cover change. Data quality assessment and product validation activities have been developed associated with these products. This paper presents a preliminary assessment of MODIS data quality and early results from the MODIS land product development.

APPENDIX 2: MODIS PM (Aqua) Data Product Description

Product Description

The MODIS vegetation index (VI) products will provide consistent, spatial and temporal comparisons of global vegetation conditions which will be used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of change detection, phenologic, and biophysical interpretations. Gridded vegetation index maps depicting spatial and temporal variations in vegetation activity are derived at 8-day, 16-day and monthly intervals for precise seasonal and interannual monitoring of the Earth's vegetation. The MODIS VI products will improve upon currently available indices and will more accurately monitor and detect changes in the state and condition of the Earth's vegetative cover. The vegetation index products are made globally robust with enhanced vegetation sensitivity and minimal variations associated with external influences (atmosphere, view and sun angles, clouds) and inherent, non-vegetation influences (canopy background, litter), in order to more effectively serve as a 'precise' measure of spatial and temporal vegetation 'change'.

Two vegetation index (VI) algorithms are to be produced globally for land, at launch. One is the standard normalized difference vegetation index (NDVI), which is referred to as the "continuity index" to the existing NOAA-AVHRR derived NDVI. The other is an 'enhanced' vegetation index **(EVI)** with improved sensitivity into high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The two VIs compliment each other in global vegetation studies and improve upon the extraction of canopy biophysical parameters. A new compositing scheme that reduces angular, sun-target-sensor variations is also utilized. The gridded vegetation index maps will use as input, MODIS AM and PM surface reflectances, corrected for molecular scattering, ozone absorption, and aerosols, and adjusted to nadir and standard sun angles with use of BRDF models. The gridded vegetation indices will include quality assurance (QA) flags with statistical data, that indicate the quality of the VI product and input data. **The MODIS vegetation index products will include:**

- 250 m NDVI and QA at 8-,16-day and monthly (high resolution)
- 1 km NDVI, EVI, and QA at 8-, 16-day and monthly (standard resolution)
- 25 km NDV, EVI, and QA at 8-, 16-day and monthly (coarse resolution)

Research & Applications

Due to their simplicity, ease of application, and widespread familiarity, vegetation indices are widely used by the broader user community from global circulation climate modelers; EOS instrument teams and interdisciplinary projects in hydrology, ecology, and biogeochemistry; to regional- and global-based applications involving natural resource inventories, land-use planning, agricultural monitoring and forecasting, and drought forecasting. Some of the more common applications of the vegetation index include:

- Global warming/ climate
- Global biogeochemical and hydrologic modeling
- Agriculture; precision agriculture; crop stress, crop mapping
- Rangelands; water supply forecasting; grazing capacities; fuel supply
- Forestry, deforestation, and net primary production studies

- Pollution/ Health issues (rift valley fever, mosquito-producing rice fields)
- Desertification
- Anthropogenic change detection and landscape disturbances.

MOD 13
PRODUCT SUMMARY

Coverage:
global land surface (level 3)

Spatial/Temporal Characteristics:
8-, 16-day and monthly at 250 m, 1 km, and 0.25° resolutions

Key Science Applications:
global vegetation monitoring
biogeochemical and hydrologic modeling
health and food security
range and forestry monitoring
agriculture management

Key Geophysical Parameters:
vegetation index (NDVI & EVI)

Processing Level:
level 3, gridded

Product Type:
standard, at-launch

Science Team Contact:
A. Huete

Data Set Evolution & Applications

At the time of launch, there will be a 20-year NDVI global data set (1981 - 2000) from the NOAA- AVHRR series, which could be extended by MODIS AM and PM data to provide a long term data record for use in operational monitoring studies. The MODIS AM or PM data set can readily be composited to provide 16-day, cloud-free time series maps of vegetation activity. When both AM and PM data are combined, higher frequency, 8-day, cloud-free time series data is readily made available.

Suggested Reading

Cihlar, J. C., *et al.*, 1997.

Huete, A. R., *et al.*, 1994.

Huete, A. R., *et al.*, 1997.

Huete, A. R., *et al.*, 1999.

Myneni, R. B., *et al.*, 1997.

van Leeuwen, W. J. D., *et al.*, 1999.

APPENDIX 3. Data Management Plan

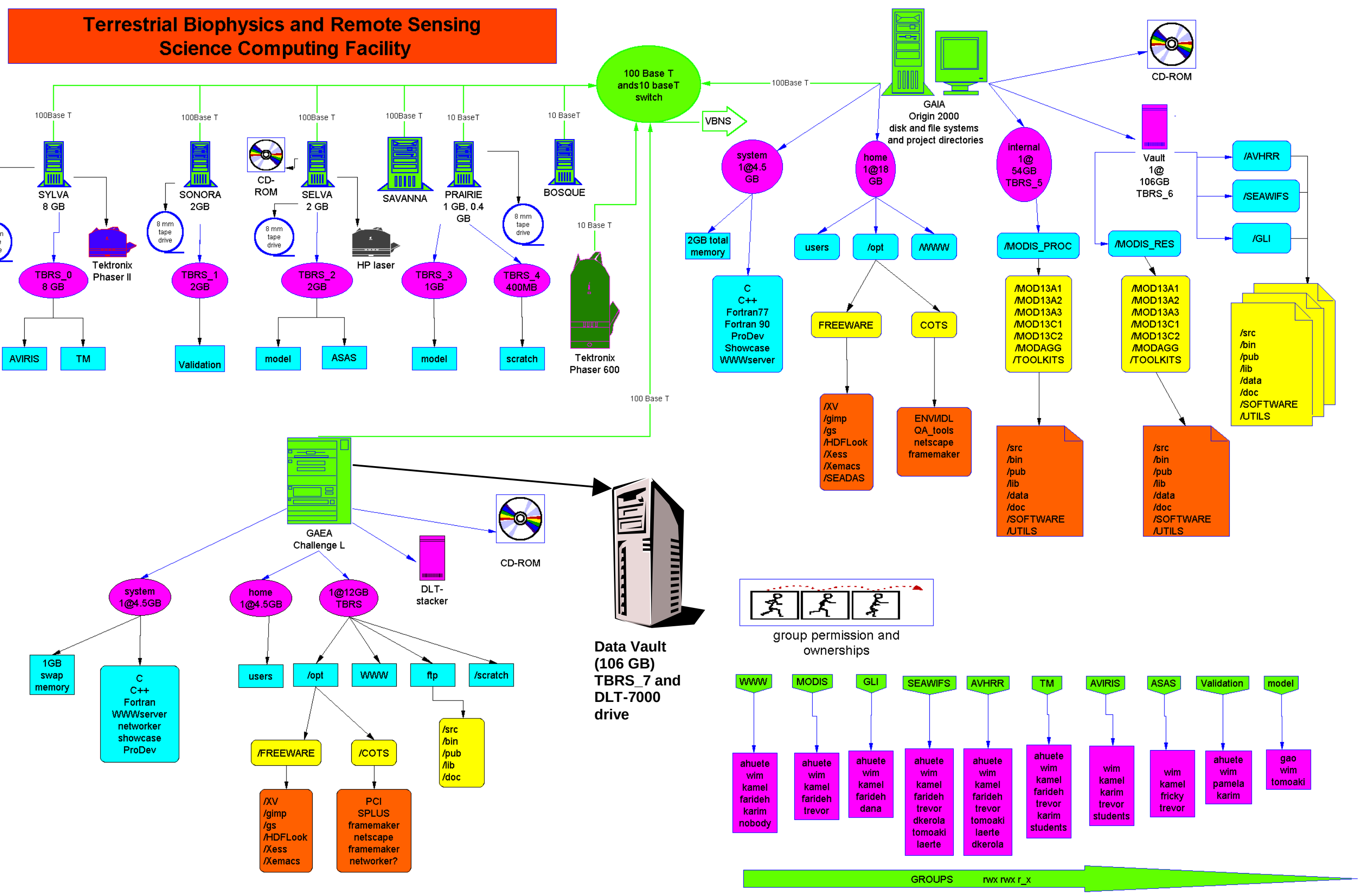

Figure 1: Network, hardware, software, disk and file system diagram of the TBRS-SCF

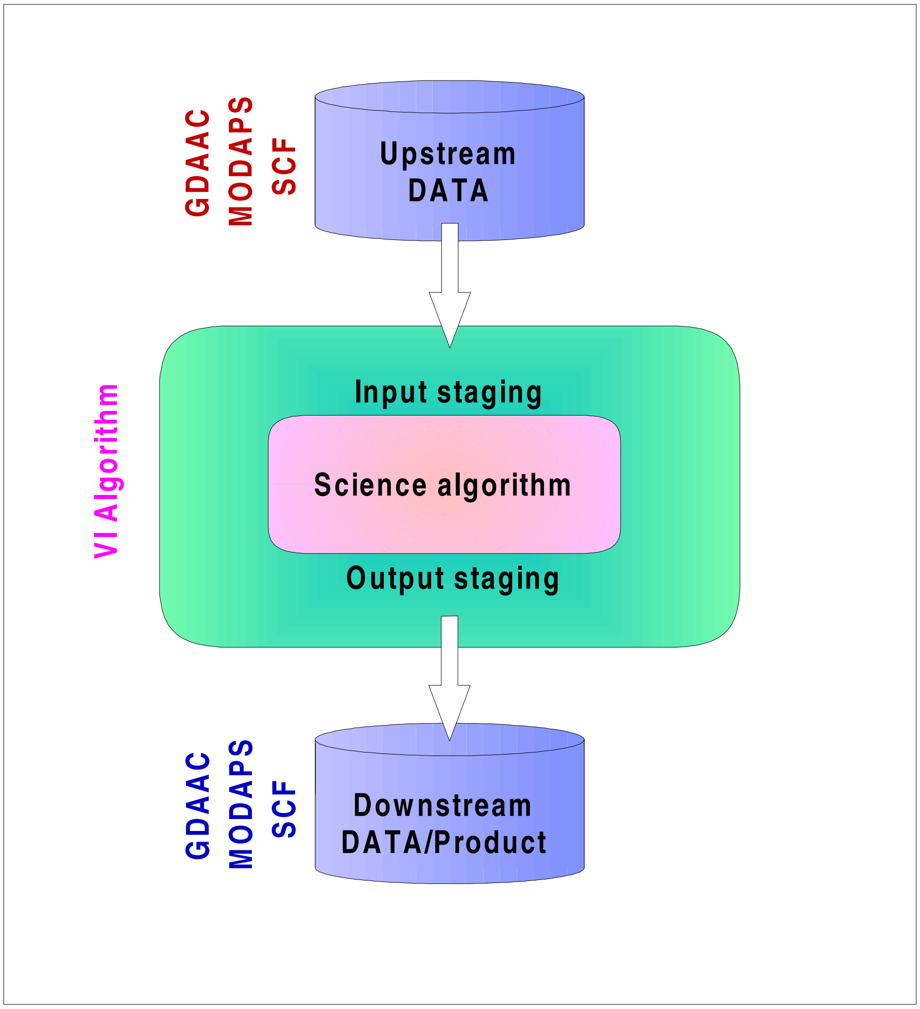

Figure 2: A diagram of the MODIS algorithm with respect to the upstream and dowstream data/products

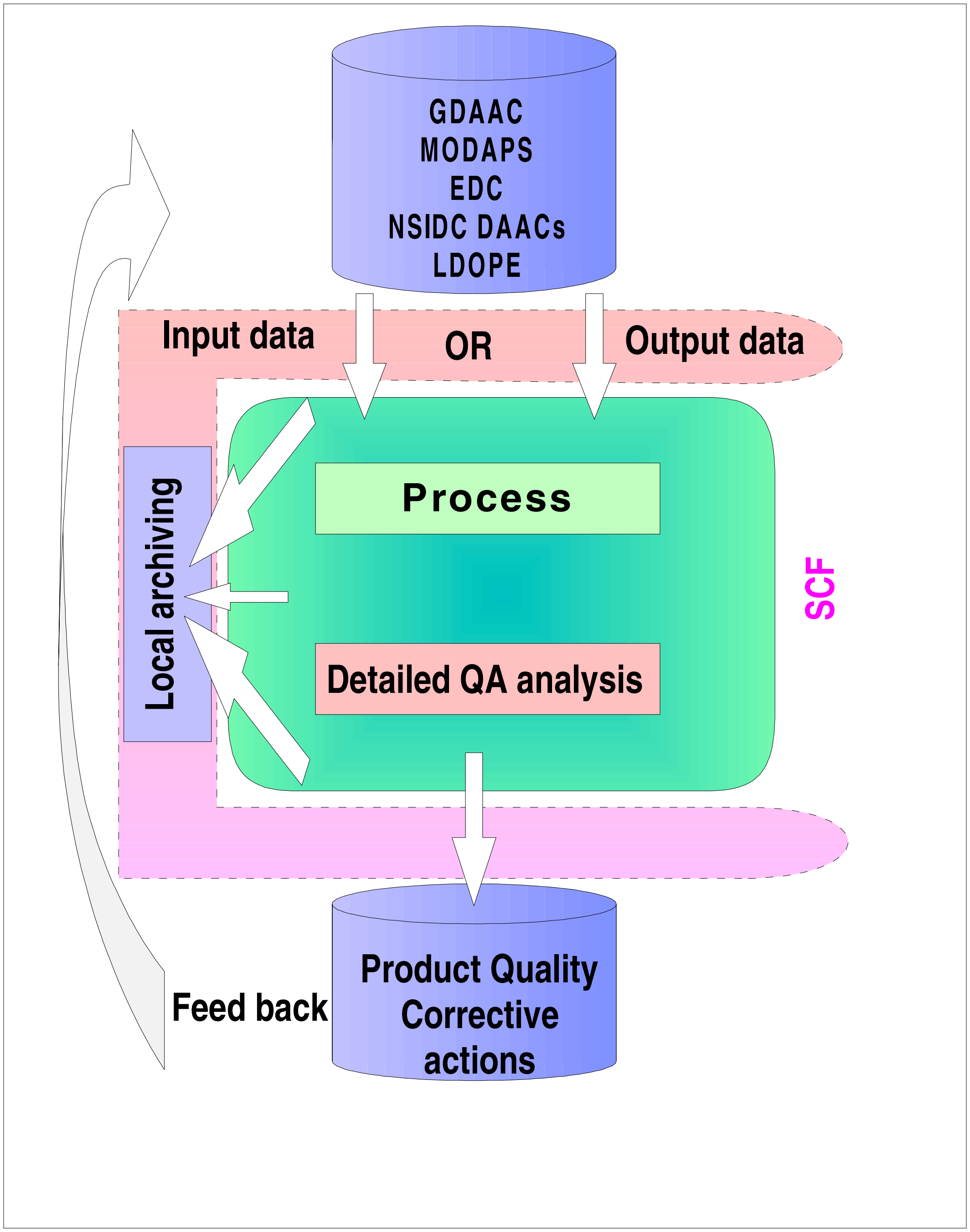

Figure 3: Generalized QA analysis and Data flow